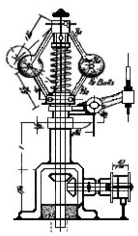


# The NEMES Gazette

NEW ENGLAND MODEL ENGINEERING SOCIETY INC.

No. 249 | February 2017

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**Dues.** It's that time of year again. Please bring your 2017 dues to the February meeting. Dues are $25 by cash, check or you can try out our credit card system. If you can't make the meeting, send the dues to NEMES, c/o Rich Baker, 288 Middle Street, West Newbury, MA **01985-1610.**

**NEMES Apparel.** We have NEMES denim button down shirts, t-shirts, sweatshirts, and aprons for sale. They make great Christmas gifts. The aprons are $20, the denim shirts $35, sweatshirts $25, and the t-shirts $15. Contact Rich Baker at 978-257-4101 if you would like to own one. You can also purchase these items on-line at the NEMES Store, located Here. [https://squareup.com/store/new-england-model-engineering-society]

**NEMES Show.** The 21st Annual NEMES show will be on February 18, 2017, at the Charles River Museum of Industry and Innovation. The show flyer is Here [http://www.neme-s.org/2017/MES%202017%20Flyer%20in%20Word-doe.pdf] Please pass it along to your friends, and/or print it out and post it at your favorite hangout.

**Next Meeting**

**Thursday, February 2, 2017, 7 PM**

Charles River Museum of Industry & Innovation
154 Moody Street
Waltham, Massachusetts
Directions are Here.

**Upcoming Speakers:**

The topics for the Feb, March, and April meetings are as follows:

February: Dan Piper, speaking on restoring South Bend lathes. (Recommended by Norm)

March: NEMES own "shaper guy" , Dave Lefkowith, speaking on metal shapers.

April: A tour of the Spencer Organ Company in Waltham. They repair pipe organs, tune them, and make some organ pipes.

**Deadline for submitting articles is two weeks prior to the next meeting.**

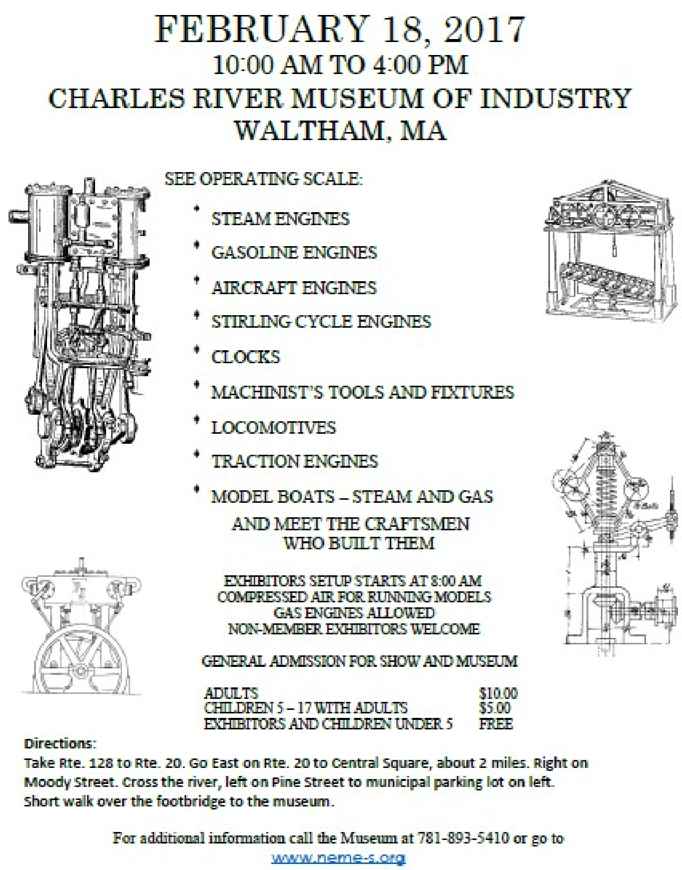
## *Table of Contents*

# $21^{st}$ Annual NEMES Model Engineering Show

It's time to plan for our annual show at the Charles River Museum of Industry, 154 Moody St. Waltham MA, on February 18, 2017 from 10:00AM to 4:00PM.

Tables and chairs will be provided as well as compressed air to run steam engine models. We will have ¼" female shutoffs at various intervals on a manifold. Bring a regulator to interface with your model. Everyone is encouraged to bring something to display. Photos, projects in progress, etc are welcome along with completed items.

This event represents one of our most significant contributions to the museum. Local advertising of this event attracts many first-time visitors to the museum. NEMES members as well as non-members are invited to exhibit at the show. Setup time is 8:00AM.



FEBRUARY 18, 2017
10:00 AM TO 4:00 PM
CHARLES RIVER MUSEUM OF INDUSTRY
WALTHAM, MA

SEE OPERATING SCALE:

- STEAM ENGINES
- GASOLINE ENGINES
- AIRCRAFT ENGINES
- STIRLING CYCLE ENGINES
- CLOCKS
- MACHINIST'S TOOLS AND FIXTURES
- LOCOMOTIVES
- TRACTION ENGINES
- MODEL BOATS – STEAM AND GAS

AND MEET THE CRAFTSMEN
WHO BUILT THEM

EXHIBITORS SETUP STARTS AT 8:00 AM
COMPRESSED AIR FOR RUNNING MODELS
GAS ENGINES ALLOWED
NON-MEMBER EXHIBITORS WELCOME

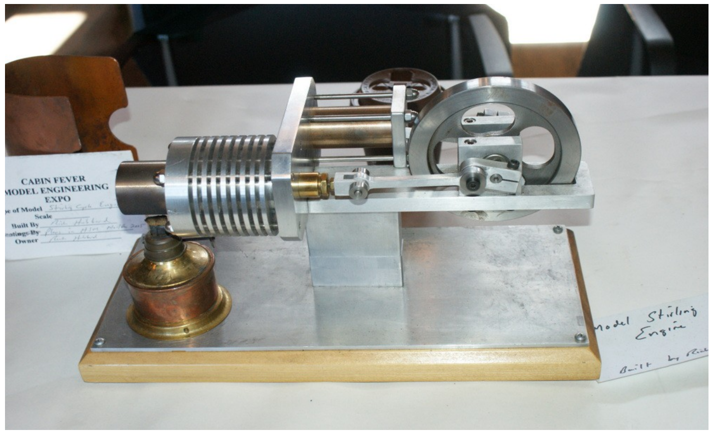
GENERAL ADMISSION FOR SHOW AND MUSEUM

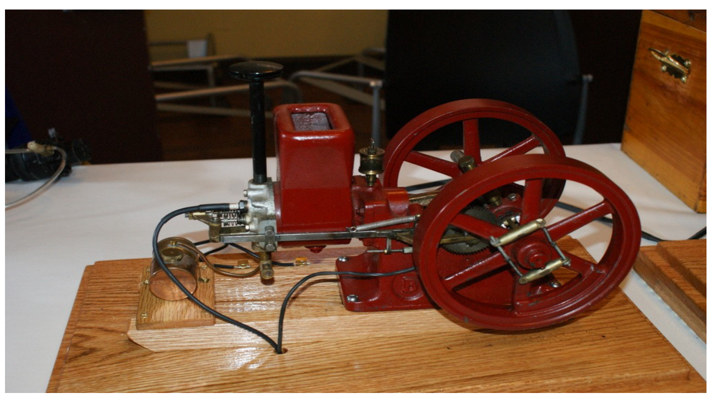
| | |
|---|---|
| ADULTS | $10.00 |
| CHILDREN 5 – 17 WITH ADULTS | $5.00 |
| EXHIBITORS AND CHILDREN UNDER 5 | FREE |

Directions:
Take Rte. 128 to Rte. 20. Go East on Rte. 20 to Central Square, about 2 miles. Right on Moody Street. Cross the river, left on Pine Street to municipal parking lot on left. Short walk over the footbridge to the museum.

For additional information call the Museum at 781-893-5410 or go to www.neme-s.org

And here are a few pictures from last year's show.



# Shop Talk

**Max ben-Aaron**

*[Editor's note: Since the 2017 version of Max is taking a breather this month, I decided to re-publish one of his very interesting older columns, this one from the December 2012 Gazette.]*

At Rollie's shop meet he brought out a very exotic piece of machinery – a Leland-Gifford Drill PointMaster sharpening machine. It is so rare that not even Frank Dorion has one (I think). This is its story:

When the Leland-Gifford company was sold, (they went to Cleveland), a friend of Rollie's attended the auction and bought an incomplete Drill PointMaster, a drill sharpener for sharpening very small drill bits. He had no use for it, so he gave it to Rollie.

Eventually, Rollie met a fellow who had been a salesman for Leland-Gifford when they were marketing the machine (only a few were made, and fewer even were bought). He looked through his files and found the manual for the machine, which he gave to Rollie.

With the aid of the manual, Rollie was able to replicate or fabricate some of the missing parts.One of the sales advantages of the sharpener was an ability to thin the point of the drill. To do this for, say, a #60 drill, the corner of the stone must be very sharp, and the machine had a method of dressing the both circumference and thef ace to achieve this end.

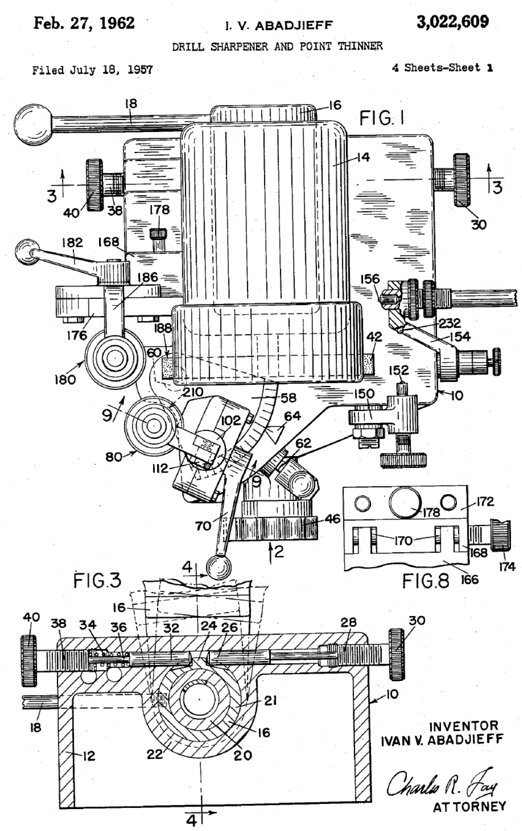
Furthermore, there was an elaborate optical system (many, many special lenses of different focal lengths) to give the operator a good view of the point to ensure sharpening symmetry. Rollie thought that the following paragraph contained some not-well-known information of sufficient value to be worth theeffort to put it in the Gazette, so here it is:

"A twist drill, unlike other tools, is structurally weak, because almost one-half of its volume has been cut away in the form of flutes to allow for discharge of the chips formed by the cutting lips, and the remainder of the tool must remove a volume equal to its own original volume. Further, it is a long, slender cut-away column under compression and subject to column action or bending at the midpoint between its support in the spindle and the drill bushing, or the work, if no bushing is used. This bending is a major factor in drilling off-line holes. Thus, you will see that for small drills, particularly,where the ratio of length to diameter is great (for example, a ratio of length to diameter equal to about 40:1), it is of utmost importance to keep the end-thrust pressure to a minimum. This is accomplished best by notching or thinning the point o eliminate as much as possible the non-cutting chisel point.

In addition to this end-thrust or column action, the drill is also subject to severe torsional stresses which are set up by the cutting lips forming the chips and by the drag of the chips in the flutes. These forces tend to make the flutes 'unwind'. Too much torsional stress, like too much end-thrust, will, of course, cause breakage. Therefore, it is important to keep your drills sharp to minimize these destructive forces.

*]There is a 1962 patent assigned to Leland that perhaps matches the design of the instrument described above:*

http://www.freepatentsonline.com/3022609.pdf]




# Union Pacific 4-8-8-4 Big Boy Locomotive

*[Errol posted a link to this very interesting article on the NEMES Yahoo:group. by William Pearce]*

***Old Machine Press:***

https://oldmachinepress.com

For some time, locomotives of the Union Pacific Railroad (UP) had struggled to climb the Wasatch mountains between Ogden, Utah and Green River, Wyoming. This 176-mile (283-km) stretch of track started out at 4,300 ft (1,310 m) above sea level in Ogden, climbed the Wasatch Range to 7,300 ft (2,225 m) at the Aspen Tunnel, and then dropped to 6,100 ft (1,859 m) at Green River. Occasionally, up to three helper engines were used to assist heavily loaded trains over the Wasatch mountains.

***Union Pacific Big Boy 4012 hauling a load of freight through Green River, Wyoming in November 1941. This may have been the recently delivered engine's first trip west. (Otto Perry image via Denver Public Library)***

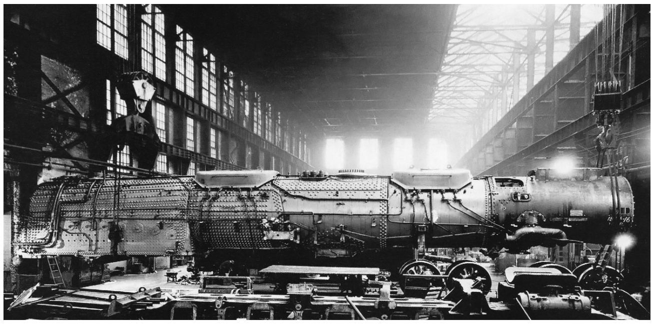
In 1940, UP was enjoying a period of expansion, and its president, William Jeffers, was interested in a new locomotive that could conquer the Wasatch Range pulling 3,600 tons (3,266 t) unassisted. At the same time, World War II was on the horizon, and the United Sates had begun to increase its production of war material. This put even more traffic on the heavily-traveled Oden-Green River route. Headed by Otto Jabelmann, UP's Department of Research and Mechanical Standards (DoRMS) in Omaha, Nebraska calculated that 135,000 lb (61,235 kg) of tractive effort was needed for the engine to achieve its design goal. DoRMS quickly designed the new, massive locomotive and worked closely with the American Locomotive Company (ALCO), the company that agreed to build the engine. The engines were assigned numbers in the 4000-class, and there were plans to name the new series "Wasatch." However, a worker wrote "Big Boy" in chalk on the front of the first engine while it was being built, and the name stuck. With its tender, the Big Boy was one of the largest and heaviest steam locomotives ever built.

The Big Boy's design was based closely on the UP's 4-6-6-4 Challenger that went into service in 1936. However, the Big Boy was larger and heavier than the Challenger and necessitated that UP make many changes to the track between Ogden and Green River. Heavier rail was laid in many places, and curves were realigned and adjusted to maintain a constant curvature. At stations, larger turntables were installed to accommodate the Big Boy's length. The Big Boy was essentially the largest thing that could normally operate on an existing standard gauge railroad.


***The crew standing next to newly-completed Big Boy 4002 gives scale to every part of the engine: the cylinders, wheels, boiler, etc. The railing on the front of the -1 class engines was originally coolers for the air pump. The -2 class used a standard Wilson aftercooler, as the custom set up on the Class -1 would often crack. As the coolers failed on the -1 class, they were removed and replaced by Wilson units. (Union Pacific image)***

The Big Boy utilized a 4-8-8-4 wheel arrangement and was the only locomotive to do so. At the front of the engine was a four-wheel leading truck that had 36 in (.91 m) wheels. This was followed by eight 68 in (1.73 m) drive wheels, with a single piston driving a set of four wheels on each side of the engine. Another set of eight drive wheels followed that were identical to the first. Finally, under the cab was a four-wheel trailing truck with 42 in (1.07 m) wheels. The leading truck and first eight drive wheels were attached to a separate frame than the second set of drive wheels and trailing truck. Between the two sets of drive wheels was a tongue and groove pivot point that allowed the front frame to articulate independently of the rear frame. Mounted to the rear frame was the boiler, firebox, and cab. The articulated locomotive was pioneered by Swiss engineer Anatole Mallet and could handle tighter curves than a standard ridged locomotive. In the case of a long locomotive like the Big Boy, articulation allowed the engine to operate on tracks with curves as sharp as 20 degrees.

ALCO built the Big Boys in Schenectady, New York, and two versions of the engine were made. Starting in 1941, 20 of the 4-8-8-4-1 class engines were made and numbered 4000–4019. In 1944, five of the 4-8-8-4-2 class engines were made and numbered 4020–4024. The difference between the two versions was mainly a different superheater that necessitated changes to the tubing arrangement in the boiler and increased water storage capacity in the tender. These changes were made for maintenance reasons and also due to material shortages during World War II. The first engine, 4000, was delivered to UP in Omaha on 5 September 1941.



***The Big Boy's firebox (left), boiler (middle), and smokebox (right) were all mounted as a single unit and can been seen here, ready to be lowered onto the engine's frame. The steel that formed the boiler was 1.375 in (35 mm) thick. The two humps above the boiler are the sandboxes. Between the sandboxes is the steam dome, its exposed studs waiting for the cover plate. Exiting the lower part of the smokebox is a duct to feed steam from the superheater to the cylinders. (ALCO image)***

All Big Boys were 132 ft 10 in (40.5 m) long and made up of an 85 ft 9.5 in (26.2 m) long engine and a 47 ft .5 in (14.3 m) long tender that carried the locomotive's coal and water. The locomotive was 16 ft 2.5 in (4.9 m) tall, and its whistle was mounted horizontally so as to not increase the engine's height. Various ladders and handholds were recessed into the engine and tender to keep the locomotive's width at a maximum of 11 ft 6 in (3.5 m). The loaded weight of the -1 class was 762,000 lb (345,638 kg) for the engine and 427,500 lb (193,911 kg) for the tender, which gave a total weight of 1,189,500 lb (539,549 kg). The -2 class was heavier at 772,250 lb (350,276 kg) for the engine, 436,500 lb (197,993 kg) for the tender, and a total weight of 1,208,750 lb (548,280 kg). Each set of eight driving wheels supported 540,000 lb (244,940 kg) on the -1 class and 545,200 lb (247,299 kg) on the -2 class. The maximum weight permitted on each of the engine's 12 axles was 67,800 lb (30,754 kg).

The centipede-style tender was supported by 14 wheels, each 42 in (1.07 m) tall. The first four wheels made up the leading truck, and the 10 trailing wheels were mounted directly to the tender. The tender originally carried 56,000 lb (25,401 kg) of coal in a front compartment. In the late 1940s, 10 in (254 mm) tall steel sideboards were added to the top of the coal compartment. The sideboards enabled an additional 8,000 lb (3,629 kg) of coal to be loaded, increasing the tender's capacity to 64,000 lb (29,030 kg). A rear compartment held 24,000 gallons (90,850 L) of water for the -1 class and 25,000 gallons (94,635 L) of water for the -2 class. At full steam, a Big Boy engine would consume the tender's coal and water supply in two hours, but a proper facility could replenish the coal and water in eight minutes.


***This image of engine 4023's tender helps illustrate why the type is known as a centipede tender. Visible on this side are the five wheels mounted to the tender and the two installed in the leading truck. The diagonal row of rivets indicates the partition between the water tank in the rear of the tender and the coal bunker in the front. Note the recessed ladder on the left and the 10 in (254 mm) sideboards atop the tender on the right. (Larry Pieniazek image via Wikimedia Commons)***

A large, mechanical stoker auger transported coal from the supply in the tender to the engine's firebox; no regular fireman could keep up with the Big Boy's prodigious need for fuel. The firebox was 235 in (5.97 m) long and 96 in (2.44 m) wide and burned coal at around 2,000 °F (1,093 °C). Heat from the firebox flowed through the boiler via a series of tubes, each 22 ft (6.7 m) long. The -1 class engine had 259 tubes: 75 2.25 in (57.2 mm) tubes and 184 4.0 in (101.6 mm) flues. With its altered boiler, the -2 class engine had 285 tubes: 212 2.25 in (57.2 mm) tubes and 73 5.5 in (139.7 mm) flues. If laid end-to-end, the tubes and flues would stretch 5,698 feet (1,737 m) for the -1 class and 6,270 feet (1,911 m) for the -2 class. After passing through the tubes, the soot, embers, smoke, and heat from the burning coal flowed into a smokebox at the front of the engine and then out into the atmosphere via dual stacks.

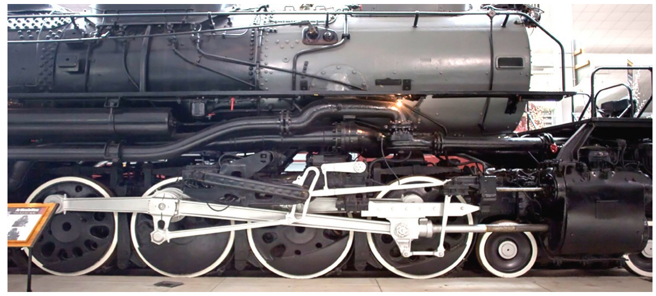
The hot tubes, flues, and firebox provided the surface area to turn water in the boiler to steam. The -1 class had 5,889 sq ft (547.1 sq m) of evaporative surface area, and the -2 class had 5,755 sq ft (534.6 sq m). The water in the boiler was heated until 300 psi (20.7 bar) of steam had been generated. With a temperature of over 420 °F (215 °C), the wet, saturated steam was collected in a steam dome positioned above the boiler. The steam flowed from the dome to the saturated steam chamber in the superheater. Small superheater elements (tubes) took the wet steam back into the flues where it was heated well above its saturation value and converted to dry, superheated steam. The superheater elements delivered the dry steam to the superheated steam chamber in the superheater. Combined, the superheater elements stretched for over a mile (1.6 km). The -1 class had a Type E superheater with a surface area of 2,466 sq ft (299.1 sq m). The -2 class had a Type A superheater with a surface area of 2,043 sq ft (189.8 sq m). The Type A required less maintenance than the Type E and provided more than enough steam for the engine, and this is why the older Type A superheater was used.

From the superheater, steam was piped to the Big Boy's two sets of two cylinders

***The smokebox of engine 4014 as it undergoes restoration. The workers inside give some perspective to the immense size of the Big Boy. The large vertical ducts are the engine's dual stacks. The large pipes behind the stacks and leading down the side of the smokebox take steam from the superheater to the cylinders. The vertical tubes are the superheater elements, and just beyond them are the horizontal tubes and flues that extend through the boiler to the firebox. (Union Pacific image via video screenshot)***

The Walschaerts valve gear controlled the flow of steam in and out of the cylinders. A piston valve mounted in a valve chest above each cylinder slid back and forth to allow steam to enter one side of the double-acting cylinder while simultaneously opening the other side to the atmosphere for the previous steam charge to escape. The steam flowed into the front of the cylinder and filled its 14,176 cu in (232 L) volume, pushing the 23.75 in (603.3 mm) diameter piston back 32 in (812.8 mm) to the rear end of the cylinder. The valve then slid rearward to open the front part of the cylinder to the atmosphere and direct steam into the rear part of the cylinder. The second blast of steam pushed the piston back to its original position. Although the cylinder was uniform in size, the cylinder's return volume was only 13,345 cu in (219 L) on account of the 5.75 in (146 mm) diameter, hollow piston rod taking up some room. The piston rod was attached to the connecting rod via a crosshead. The connecting rod extended back to the third driving wheel in the four-wheel set. Here, the connecting rod was attached to the coupling rod, which was connected to all four driving wheels. To aid traction, sand could be deposited on the rails in front of each drive wheel. The Big Boy had two sandboxes mounted on top of the boiler and each held 4,000 lb (1,814 kg) of sand.

The Big Boy was designed for a top speed of 80 mph (129 km/h), but its highest speed reported was a test at 72 mph (116 km/h). It is unlikely the engine was ever operated in service much beyond 50 mph (80 km/h). Of course, hauling the heaviest loads up the steepest grades reduced the engine's speed to around 12 mph (19 km/h), the speed at which its tractive effort was at a maximum of some 135,375 lb (61,405 kg). The 80 mph (129 km/h) speed design ensured that parts were built to withstand stresses well beyond what was needed to haul freight at 40 mph (64 km/h).



***The front drive wheels on engine 4017. The black box on the right is the cylinder, with the piston rod extending out to the left. A crosshead joins the piston rod with the connecting rod. The connecting rod extends back and attaches to the third drive wheel, and a coupling rod connects all the drive wheels together. (National Railroad Museum image)***

At 41 mph (66 km/h), the Big Boy produced some 6,290 hp (4,690 kW) at the drawbar, which would be around 7,157 hp (5,337 kW) produced at the cylinders. Without any slip, each rotation of the drive wheels moved the engine 17.8 ft (5.4 m). At 41 mph (66 km/h), each drive wheel rotated 202 times a minute, and each double-acting piston made 404 strokes. This resulted in roughly 12,869 cu ft (364 cu m) of steam passing through the Big Boy's cylinders every minute.

Four seats were provided in the Big Boy's cab, although the engine only required a crew of three: an Engineer, a Fireman, and a Brakeman. If needed, the cab could accommodate six occupants with two additional makeshift seats. Each of the 20 -1 class engines cost $265,174 in 1941, and each of the five -2 class engines cost $319,600 in 1944. The equivalent cost for each engine would be over $4,335,000 in 2016.

***Smoke and steam billow out of Big Boy engine 4017 as it starts off from Rawlins, Wyoming. Even though it is a -1 class, the cooler has been removed from the railing on the front of the engine. (Stan Kistler image)***

All Big Boy locomotives were pressed into service as soon as they could be delivered. Originally cleared to pull 3,200 tons (2,903 t) up the 1.14% grade between Ogden and Green River, the engines were eventually allowed to haul 4,450 tons (4,037 t) as experience was gained. On a .82% grade, the engines were cleared to haul 5,360 tons (4,863 t). Theoretically, the Big Boy could pull a train 5.5 miles (8.9 km) long on flat ground from a standing start. In practice, the engine routinely pulled over 100 cars.

During World War II, the Big Boys spent most of their time moving freight between Ogden and Green River. On a typical run from Oden to Evanston, Wyoming, with a stop in Echo, Utah, a Big Boy would take about four hours to cover the 76-mile (122-km), uphill route and climb some 2,500 ft (762 m). Engine 4016 made the trip in 3 hours and 50 minutes while hauling 71 cars, for a weight of 3,883 tons (3,523 t). The Big Boy consumed 74,700 lb (33,883 kg) of coal and 34,800 gallons (131,732 L) of water. This averages to 19,487 lb (8,839 kg) of coal and 9,078 gallons (34,364 L) of water used per hour, or 996 lb of coal and 464 gallons of water per mile (280 kg and 1,089 L per km). Under full steam, the Big Boy was said to consume 22,000 lb (9,979 kg) of coal and 12,000 gallons (45,425 L) of water per hour.

***To expedite service, especially with heavy trains, even the Big Boy used helper engines or was doubleheaded. Here, engines 4013 and 4004 team up to doublehead a train over Sherman Hill on the way from Laramie to Cheyenne in August 1958. (Otto Perry image via Denver Public Library)***

After World War II, Big Boys were occasionally used for trips to southern Utah and did make regular trips into Wyoming, going as far as Cheyenne, 483 miles (777 km) from Ogden. The Cheyenne trips required conquering the 1.55% grade up Sherman Hill and passing through the Hermosa Tunnel at around 8,000 ft (2,438 m). In the 1950s, their service expanded on occasion as far east as North Platte, Nebraska and as far south as Denver, Colorado. Although the engines were cleared for other routes, like Ogden to Los Angles, they never made the journey in regular service. The ever-increasing tonnage needing to move on the rails resulted in even the Big Boys using helper engines to speed up travel over the steep mountain passes. Rarely, two Big Boy engines would be linked to doublehead a train quickly over the mountain.

The Big Boy engines proved very reliable in service, but they did require a significant amount of maintenance. UP considered purchasing additional engines, and other railroads thought about buying Big Boys, but resources were somewhat limited during World War II. After the war, diesel locomotives were proving themselves as the prime mover of the future. Still, Big Boys soldiered on and were one of the last steam locomotives in regular service.

***Well-worn engine 4021 hauls freight through Wyoming in June 1956. The Big Boys were one of the last steam engines in regular service. (Chris Zygmunt Collection image)***

The last Big Boy was removed from revenue service on 2 July 1959. The engines were kept in storage until August 1961, when the first were retired. The last Big Boy was retired in July 1962. At the time of their retirement, each of the -1 class Big Boys had accumulated over 1,000,000 miles (1,610,000 km)—the equivalent of traveling from the Earth to the Moon and back twice. Engine 4006 had the most miles, at 1,064,625 (1,713,348 km). Each of the -2 class engines had traveled over 800,000 miles (1,290,000 km)—the equivalent of circling the Earth 32 times. At 855,163 miles (1,376,252 km), engine 4021 had the highest mileage of the -2 class. All total, the Big Boys accumulated 25,008,054 miles (40,246,574 km); this is about the distance from Earth to Venus when the planets are at their closest point.

Although the Big Boy was very impressive, there were other locomotives that were larger, heavier, and more powerful, but probably none that were all three. What makes the Big Boy unique is that even with its massive size and colossal power, it was in regular service for nearly 20 years—it was not an experimental train, and it was not limited to a small section of track. The Big Boy was also not a Mallet-type locomotive. Although it was articulated, the Big Boy was not a compound steam engine, which is the second hallmark of a true Mallet.

Seventeen of the Big Boy engines were scrapped, while the remaining eight were put on display in various museums. As of 2016, seven of the Big Boys are still on display. The remaining engine, 4014, was reacquired by UP in 2013 and is undergoing restoration to working order at their facility in Cheyenne, Wyoming. The restoration is planned to be completed by 2019, in time for UP’s 150th anniversary. However, the amount of work needed to return 4014 to working order is substantial. Part of the restoration includes converting the engine from coal fired to oil fired. Regardless, Big Boy 4014 will once again take to the rails, but only for special excursion service; its days as a workhorse ended some 50 years ago.

***Big Boy 4014 sits in Cheyenne undergoing restoration. The cab has been removed, and the locomotive has been stripped down to the boiler. (Union Pacific image)***

***Sources:***

*Big Boy* ***by William W. Kratville (1972)***
***"Big Boy: On the Road to Restoration"*** *Trains Magazine Special* ***(2014)***
*Last of the Giants* ***(Part 1 and Part 2) by Union Pacific***
***http://www.steamlocomotive.com/bigboy/?page=up***
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***https://en.wikipedia.org/wiki/Union_Pacific_Big_Boy***
***http://www.american-rails.com/big-boy.html***
***http://www.northeast.railfan.net/bigboy.html***
***http://www.trainweb.org/brettrw/maps/evanstonsub/evanstonsubmap.html***

## *From the Gazette Archives*

*[From the September 2000 Meeting]*

The main speaker for the evening was Cal Guiry. He started working for Fafnir Bearings in 1950.

In 1909 in New Britain Connecticut, Hart and Cooley wanted to build a car. They went toEliza Cooper and asked him to make a ball bearing machine so that they could have ball bearings in the cars spring shackles. He made them a machine in six months. Then someone else came to him to ask about making a double bearing pillow block for line shafts. This pillow block used two ball bearings, the block was self aligning, but not the bearings inside it.

At that time most of the ball bearings that were available came from Europe and Cooper had problems with the imported competition. He asked his wife to come up with a suitably European sounding name and she picked Fafnir. Fafnir is the magician from Wagner's operas. The logo was a dragon in a bearing. Fafnir made ball bearings from 1/16 inch to 4 1/2 inch diameters.

Most bearings today are made from 52100 steels. These are not stainless steels, but do contain a lot of nickel. The balls are made from 51100 steel. 440C is a stainless that is sometimes used in ball bearings.

Machining the inner and outer rings is a precision job, but making the balls is the most interesting part. Up to 1/2 inch balls are made from wire. The wire hits a stop and is cut off. The piece goes into a hammer with cups in the face and formed into a rough sphere. From there it goes into a machine were it goes between two stones rotating in opposite directions. The stones grind the balls into spheres as they roll between the two moving surfaces.

From rough grinding they balls go into heat treat, where they are heated to 1200 degrees for two hours. Then they are quenched in oil and the temper is drawn for five hours at 400 degrees. The balls are tested for proper heat treat by holding three of them in a Vblock for alignment and giving them a bang so one splits evenly in half. The split is then examined to insure that all is well.

After heat treat they go into size grinding. This time there is a cast iron wheel on one side and a stone wheel on the other. When they are within a tenth they go between two iron wheels within a slurry of lime. They might spend about a week and a half here. After being ground to size the balls go into polish, where they spend two weeks in ground corncob. After the corncob polish bare human hands do not touch the balls. They are sorted for size by sixteen graduated holes and checked for proper hardness with a bounce test. The balls that go into a bearing will be within 30 millionths of each other in size.

To assemble a bearing the inner and outer races are held offset and all but one bearing is dropped in. Then at the next station a machine squeezes the races together and the last ball is added.

Most bearings today are metric but Fafnir still has an inch series from 1/8 to 4 inches in size. The race for a bearing is two per cent more open than the diameter of the ball, so blue on the ball gives an elliptical mark on the race. This controls end shake. End shake is between 2 and 5 thousandths. Radial shake is less than 5 thousandths. For every tenth over the recommended interference between the bearing and the shaft or housing, you lose eighty per cent of the clearance in the bearing.

How do you get the desired preload on a bearing pair? Support the bearing by the outer race, and apply the desired load to the inner race. Measure the deflection. Grind the outer race so that when two bearings are pulled together the inner races push out each other the required amount for the desired preload.

A good sealed bearing should run for five years solid providing it is not over speeded and that it is not subjected to such large radial loads that it spalls. More bearings are lost due to over lubing than to under lubing.

Bearings come in ABCE classes 1, 3, 5, 7, and 9. They are all made the same way, but on different machines in different departments. For higher classes the inner and outer races are more carefully made.

Heal Machinery in Worcester Mass makes the best machinery for bearing races. Most of the polished bearings are sold to people who put them into vacuum cleaners. One of the listeners said that he has sent big bearings such as are used in rotating excavators and cranes on their bases to Avon Bearing in Ohio to be rebuilt. These bearings are 7 or 8 feet in diameter, weigh several tons each, and can cost$25,000 new. Cal says that he's familiar with Avon and that they do a good job.

Brinelling is when the balls put dents into the races. This was a problem with car wheel bearings where the cars were vibrated on a train or ship without the wheels turning so that when the new car arrived at the dealer to be sold the wheel bearings were already no good.

For grinder spindle bearings you need the bearings to be preloaded. Test the bearings for runout. You need less than one tenth runout for a grinder spindle. There is repeatable runout and non-repeatable runout. When a ball in the bearing is bigger than the rest you will notice the difference after nine turns of the bearing. You want a high precision bearing when you are making a grinding spindle.

Terminal velocity of a bearing occurs when the centrifugal force on the balls reaches the radial capacity of the bearing. In order to make the large bearings in jet engines and such that turn fast able to turn faster, the balls are hollow. M50 tool steel hemispheres one eighth of an inch thick are welded together to make the balls. Bronze retainers with a silver coating are used. Air mist lube is the best for a bearing, and many of the current jet engines have systems to provide a deluge of air mist to the bearings after landing when conditions are the harshest.

How does lubrication affect the acceptable speed for a bearing? If a given bearing will operate at 500 RPM with grease lubrication, it could do 20000 RPM with air mist lubrication (one drop per minute.)

Roller bearings are now used in the front wheels of cars to avoid the brinelling problem. Cal had a bunch of Heal Borematic heads on a rack that was vibrating and it ended up ruining the bearings in about 60 heads.

About 98% of the balls are good. That's because they are very careful at every step of the process while making them. Asian ball bearings are excellent. After all, we taught Japan how to make them. Since WWII India, Russia, and Sweden also make ball bearings. MRC, New Departure, Fafnir, and SKF all make good bearings.

Loctite brand Adhesive for Bearings is good to a 5 thou fit. If you press the inner and outerboth you've got a tricky situation because of the potential for losing all the clearance in the bearing - you can brinell them just installing them. Using the adhesive to secure the bearing you don't run this risk.

Finally the subject of ball bearing races came up. This is where you hold the inner race, blow on the outer race with compressed air to get it spinning, and then drop it onto the floor and watch it race across the room. It is not recommended because it is possible to overstress the outer race, turning it into shrapnel and probably doing a real number on your hand at least. So, don't do it.


## Coming Events

**Errol Groff**

18 February 21st Annual NEMES Model Engineering Show @ the Charles River Museum of Industry

154 Moody Street, Waltham M

Show flyer HERE

[http://www.neme-s.org/2017/ME%202017%20Flyer.pdf]

Museum website HERE [https://www.charlesrivermuseum.org/]

## Sources for Model Engineering Parts and Supplies

*[The following link is courtesy of NEMES member John Bottoms]*

http://www.metricscrew-toolco.com/

**Metric Screw & Tool Company**